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(71) Applicant : **IMPERIAL CHEMICAL  
INDUSTRIES PLC**  
Imperial Chemical House, Millbank  
London SW1P 3JF (GB)

(72) Inventor : Morpeth, Fraser Forrest  
6 Gleneagles Way  
Ramsbottom, Bury, Lancashire BL0 9QN (GB)

(74) Representative : Pugsley, Roger Graham et al  
**IMPERIAL CHEMICAL INDUSTRIES PLC Legal**  
Department: Patents PO Box 6 Bessemer  
Road  
Welwyn Garden City Herts, AL7 1HD (GB)

(54) Biocide composition and use.

(57) A composition which contains a 4,5-polymethylene-4-isothiazolin-3-one and either a 2-halo-2-halomethylglutaronitrile or a defined isothiazolinone which is different from the 4,5-polymethylene-4-isothiazolin-3-one and which can be a 4,5-optionally halogenated N-alkyl isothiazolin-3-one. The compositions exhibit anti-microbial activity and certain combinations are surprisingly effective against bacteria.

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The present invention relates to compositions which are useful as industrial biocides.

Industrial biocides are useful to prevent industrial spoilage, in particular that caused by bacteria and fungi. Industrial biocides find application in the preservation of paints, latices, adhesives, leather, wood, metal working fluids and cooling water.

One class of compound which can be used as an industrial biocide is based on the isothiazolinone structure. There are many disclosures of isothiazolinone derivatives which are stated to have useful biocidal properties. US Patent 3761488 discloses isothiazolinone derivatives in which alkyl, alkenyl, alkynyl, cycloalkyl, aralkyl or aryl groups, which may optionally be substituted, are attached to the nitrogen atom and the 4 and 5 positions are unsubstituted or are substituted with halogen or lower alkyl groups. US Patent 4165318 discloses a solution of an isothiazolin-3-one in a polar organic solvent, wherein the solution also contains a stabilising amount of formaldehyde. Stabilisation of similar compounds is also claimed in US Patent 4,067,878 where the stabilising compound is a nitrite or nitrate of a metal cation. British Patent Specification 2087388 discloses 4,5-polymethylene-4-isothiazolin-3-ones and derivatives thereof in which the polymethylene chain has three or four carbon atoms.

A further class of compounds which have found a use as industrial biocides are the 2-halo-2-halomethyl glutaronitriles. Such compounds have been disclosed and claimed in USP 3,833,731 inter alia.

Compounds and compositions of the foregoing types, and related compounds of the same general type, are effective to a varying degree, depending on the particular compound or composition, against a range of bacteria and/or fungi. However, to reduce the cost of using these compounds it is desirable to improve their effectiveness as antimicrobial materials.

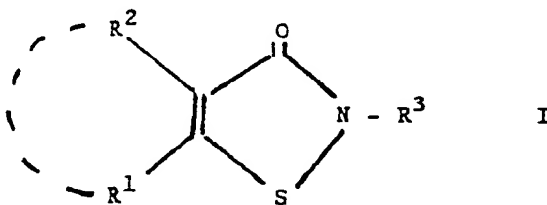
Compositions have been proposed which contain more than one compound which has antimicrobial properties. In general such compositions show an aggregate of the properties of the compounds present in the composition. Typically such compositions contain one compound which exhibits useful antibacterial properties together with a different compound which exhibits useful antifungal properties.

We have now found that certain compositions possess surprisingly useful antimicrobial especially anti-bacterial properties.

Thus, according to the present invention there is provided a composition which comprises

- (a) at least one 4,5-polymethylene-4-isothiazolin-3-one or a derivative thereof, and
- (b) at least one 2-halo-2-halomethyl glutaronitrile, or
- (c) at least one isothiazolin-3-one derivative which does not contain a fused ring attached to the isothiazole ring.

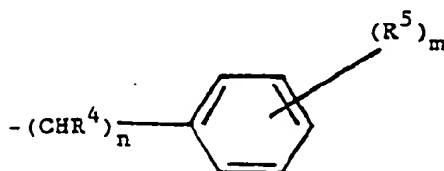
The 4,5 polymethylene-4-isothiazolin-3-one derivative which is component a) of the composition is typically a compound of the general formula I.



wherein:

R<sup>1</sup> and R<sup>2</sup> taken together represent a polymethylene chain, having 3 or 4 carbon atoms or a polymethylene chain having 3 or 4 carbon atoms substituted by at least one lower alkyl radical having from 1 to 4 carbon atoms;

R<sup>3</sup> represents hydrogen; a linear or branched alkyl group having from 1 to 12 carbon atoms; a linear or branched alkyl group having from 1 to 3 carbon atoms substituted by one or more hydroxyl groups; an alkenyl group having from 3 to 6 carbon atoms; a radical of the formula



wherein:

n is 0 or 1;

m is 1 or 2;

R<sup>4</sup> represents hydrogen or a lower alkyl group; and

5 R<sup>5</sup> represents hydrogen, lower alkyl, nitro, trifluoromethyl or halogen, preferably chlorine, bromine or iodine; cyclo alkyl having from 3 to 6 carbon atoms; and a radical of formula



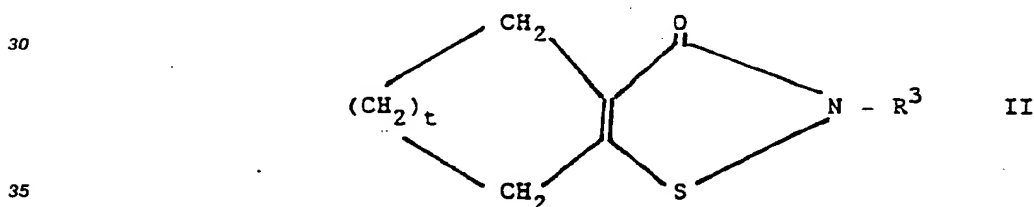
wherein

15 R<sup>6</sup> represents hydrogen, linear or branched alkyl having from 1 to 12 carbon atoms or a radical of the formula



25 as defined above, and their salts or complex with a mineral or organic acid, or with a base.

In a preferred embodiment of the invention the 4,5-polymethylene-4-isothiazolin-3-one can be represented by the general formula II



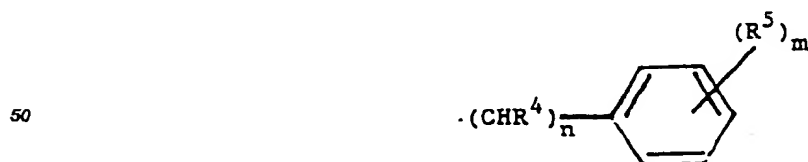
wherein t is 1 or 2 and R<sup>3</sup> is as defined above. These compounds are, thus, derivatives of 4,5-trimethylene or 4,5-tetramethylene-4-isothiazolin-3-ones.

40 R<sup>3</sup>, in formulae I and II, may be a linear or branched alkyl group, such as methyl, ethyl, propyl, isopropyl, butyl, isobutyl, tert-butyl, hexyl, octyl or dodecyl.

When R<sup>3</sup> represents alkyl substituted by one or more hydroxyl groups, this includes, for instance, hydroxymethyl, 2-hydroxyethyl, 2-hydroxypropyl and 1,2 dihydroxy propyl.

As an example of alkenyl as represented by R<sup>3</sup>, there may be mentioned allyl.

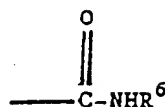
45 When R<sup>3</sup> represents a radical of formula



55 this can be, for example, phenyl, chlorophenyl, 2,4-dichlorophenyl, benzyl, 4-chlorobenzyl or 2,4-dichlorobenzyl.

When R<sup>3</sup> represents cycloalkyl having from 3 to 6 carbon atoms, this can be, for example, cyclopropyl, cyclobutyl, cyclopentyl or cyclohexyl.

When R<sup>3</sup> represents a radical of formula



it can be carbamoyl, N-methyl carbamoyl, N-ethylcarbamoyl, N-isopropyl carbamoyl, N-propyl carbamoyl, N-phenyl carbamoyl, N-cyclohexyl carbamoyl, N-butyl carbamoyl or N-octyl carbamoyl.

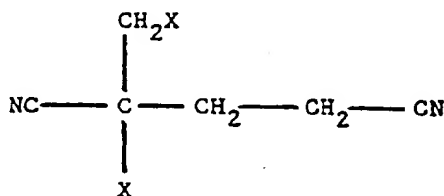
Finally, when the compound of formula I forms a complex with a base,  $R^3$  is a cation. This cation may have a valency of more than one, but is particularly a monovalent cation such as an alkali metal, an amine or quaternary ammonium cation.

The salts formed between the compound of formula I and a mineral or organic acid, and the complexes formed between the compound of formula I and a base are generally water soluble and hence can be used in aqueous solution.

The term lower alkyl represented by  $R^4$  above includes linear or branched alkyl chains containing up to 4 carbon atoms such as methyl, ethyl, isopropyl, butyl and tertiary butyl.

As specific examples of compounds which may be used as component (a) of the composition of the present invention, there may be mentioned 2-methyl-4,5-trimethylene isothiazolin-3-one (formula II, in which t is 1 and  $R^3$  is methyl), and 4,5-trimethylene isothiazolin-3-one (formula II, in which t is 1 and  $R^3$  is hydrogen).

Component (b) of the composition of the present invention is at least one compound of general formula



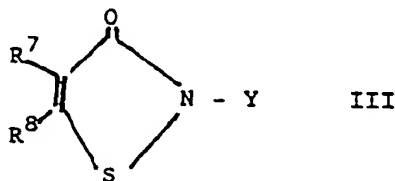
wherein

each X, which may be the same or different, is a halogen atom, especially chlorine or bromine.

Preferably, both substituents X are the same halogen, and are especially bromine atoms.

By way of examples, there may be mentioned 2-chloro-2-chloromethyl glutaronitrile and particularly 2-bromo-2-bromomethyl glutaronitrile.

Component c) of the composition is an isothiazolin-3-one of general formula III



wherein

Y is a hydrogen atom, an alkyl, substituted alkyl, alkenyl, alkynyl, cycloalkyl, aralkyl or aryl group;

$R^7$  is hydrogen, halogen or an alkyl group; and

$R^8$  is hydrogen, halogen or an alkyl group.

When Y is alkyl, it is preferably an alkyl group containing from 1 to 18 carbon atoms and especially from 1 to 4 carbon atoms and particularly a methyl group.

When Y is cycloalkyl, it is preferably a cycloalkyl group containing from 3 to 12 carbon atoms and especially from 3 to 8 carbon atoms and particularly a cyclohexyl group.

When Y is alkyl or aralkyl, it preferably contains up to 10 carbon atoms. The aryl groups, themselves, may also carry substituents such as halogen, particularly chlorine, or alkyl or alkoxy groups containing up to 4 carbon atoms such as methyl and methoxy.

When  $R^7$  and/or  $R^8$  is halogen, it is particularly chlorine or bromine, and when  $R^7$  and/or  $R^8$  is alkyl it is particularly an alkyl group containing from 1 to 4 carbon atoms and especially methyl.

Particularly important within this group of compounds are those in which Y represents a linear or branched alkyl group containing up to 8 carbon atoms and where R<sup>7</sup> and R<sup>8</sup> represent independently hydrogen or chlorine. Thus, as specific examples of compounds which may be used as component (c) of the composition of the present invention, there may be mentioned 2-methyl isothiazolin-3-one (formula III, in which Y is methyl, R<sup>7</sup> and R<sup>8</sup> are both hydrogen), 5-chloro-2-methyl isothiazolin-3-one (formula III, in which Y is methyl, R<sup>7</sup> is chlorine and R<sup>8</sup> is hydrogen) and 4,5 dichloro-2-methyl isothiazolin-3-one (formula III, in which Y is methyl, R<sup>7</sup> and R<sup>8</sup> are both chlorine). Such compounds may represent component (c) in the composition of the present invention as individual chemical compounds or they may be present in combination.

As a particular embodiment of the present invention there is provided a composition comprising 2-methyl-4,5-trimethylene-4-isothiazoline-3-one and 2-bromo-2-bromomethyl glutaronitrile.

A further particularly useful combination has been found to be one comprising 2-methyl-4,5-trimethylene-4-isothiazolin-3-one together with at least one of 2-methyl isothiazolin-3-one, 5-chloro-2-methyl isothiazolin-3-one and 4,5-dichloro-2-methyl isothiazolin-3-one.

In various types of applications, it is frequently necessary or convenient to formulate the isothiazolin-3-one as represented by formula I or formula III in solution, especially using water or polar organic solvents such as alcohols. While such formulation has no effect on the stability or function of isothiazolin-3-ones as anti-microbial agents if used relatively quickly, extended storage of the formulated solutions, especially at elevated temperature, may result in chemical decomposition of the isothiazolin-3-one, thus leading to reduced biocidal effectiveness. Consequently, it is common to stabilise such formulations by incorporating nitrite or nitrate salts of metals. It is also possible to stabilise such compounds in the presence of formaldehyde or compounds which release formaldehyde.

When isothiazolin-3-ones of the afore-mentioned structures as represented by formulae I and III are used in aqueous solution, their solubility may be improved by forming their salts with strong organic and/or inorganic acids such as hydrochloric acid, sulphuric acid, succinic and citric acids.

The relative proportions of the components of the composition can vary and compositions having useful properties can be obtained which contain from 1 part by weight of component (a) or of component (b) or component (c) and correspondingly up to 2000 parts by weight of component (b) or component (c) or component (a). The preferred proportions are dependent on the compounds used as component (a) and component (b) or component (c) and also the particular system in which the mixture is to be used.

In general the composition comprising components (a) and (b) contains one part of component (a) and at least 20 parts by weight of component (b) and in particular one part of component (a) and at least 100 parts by weight of component (b). Typically, the composition containing component (a) and component (b) contains 1 part by weight of component (a) and not more than 800 parts by weight of component (b). Particularly useful effects have been obtained with compositions containing one part of component (a) and not more than 600 parts by weight of component (b).

Generally, those compositions containing component (a) and component (c) contain at least 1 part by weight of one component and not more than 100 parts by weight of the other component.

Particularly preferred compositions comprising component (a) and component (c) are those where the ratio of component (a) to component (c) is between 1:10 and 10:1 and preferably between 1:5 and 5:1 such as, for example, 1:1.

The compositions of the present invention have antimicrobial properties. We have found that compositions in accordance with the present invention are active against both bacteria and fungi, and are especially active against bacteria. Furthermore, compositions in accordance with the present invention are such that the sum of the fractional inhibitory concentration (FIC) for all the components of the composition is less than one and, with preferred compositions is less than 0.9. Especially preferred compositions are those compositions containing component (a) and component (b) in which the sum of the FIC for all the components of the composition is not more than 0.7. The FIC is the ratio of the concentration of an individual component to the minimum inhibitory concentration of that component. It will be appreciated that if the value of the sum of the FIC for all the components of the composition is less than one, the composition is synergistic, the extent of synergy being indicated by the amount by which the sum of the FIC is below one. We have found that some compositions in accordance with the present invention are such that the sum of the FIC is less than 0.7.

In the case of compositions containing component (a) and component (c), especially preferred are those compositions in which the sum of the FIC is less than 0.6.

The compositions of the present invention have antimicrobial properties and are suitable for use as industrial biocides. They exhibit good wet state preservation and hence may be used as a cutting fluid preservative and also in cooling water applications. They may also be used in paper mill liquors. Furthermore, the composition may be used to preserve industrially important formulations, especially aqueous based formulations, which are used for coloration, such as dyestuffs and printing inks. They may also be used in the agrochemical

industries to preserve formulations such as herbicide and pesticide flowables.

Still further important applications of the compositions of the present invention include their use in hydrocarbon fluids such as diesel fuels. They may also be incorporated into adhesives in order to inhibit microbial spoilage.

5 The preservation of wood and leather is yet another important application of the compositions.

Especially important is the use of the composition of the present invention in paints, particularly in aqueous based latices.

A particularly preferred use of the compositions of the present invention is the preservation of polyvinyl acetate and particularly acrylic latices, especially those whose pH is above 7, and especially those containing ammonia or amines.

10 The materials which are component (a) and component (b) of the composition of the present invention are soluble in many polar solvents, although the solubility is dependent on the nature of the particular compounds which are present in the composition. However, many of the compounds are soluble in water, alcohols, ethers, ketones and other polar solvents or mixtures thereof.

15 The compositions of the present invention may be used alone as an antimicrobial material but may also be used in, or on, a suitable carrier material.

Thus, as a further aspect of the present invention there is provided a biocide composition comprising a carrier and an effective amount of a composition of components (a) and component (b) or component (c) in accordance with the invention.

20 The carrier is typically a material which shows little, if any, antimicrobial activity and may be, or include, a material which is susceptible to the growth of micro-organisms, particularly bacteria. The carrier is preferably a liquid medium and the biocide composition may be a solution, suspension or emulsion of the composition of components (a) and (b) in a liquid carrier. The carrier may be water, in which one or all of components (a), (b) and (c) are soluble, or may be a liquid such as acetic acid, N,N-dimethyl-formamide, propylene glycol, dimethyl sulphoxide or N-methyl-2-pyrrolidone in which at least one, and preferably all, of components (a), (b) and (c) are soluble. Alternatively, a mixture of liquids may be used, one being a solvent for component (a), (b) and (c) and the other being a non-solvent for all components, and using such a mixture the composition typically comprises an emulsion or droplets of a solution of components (a), (b) and (c) in the solvent therefor dispersed in the non-solvent. If a suspension or emulsion is used, this conveniently contains a surface active agent which is effective to maintain the non-continuous phase as a suspension or emulsion. Any surface active agent known for use in biocide compositions may be used in such a system, for example alkylene oxide adducts of fatty alcohols, alkyl phenols and amines such as ethylene diamine.

Whereas it is advantageous in using the composition of the present invention to add component (a) and component (b) or component (c) simultaneously, it will be appreciated that in certain circumstances it may be beneficial to add component (a) and component (b) or component (c) sequentially.

35 The amount of the composition which is present in the biocide composition may be just sufficient to have an antimicrobial effect or the composition may be present in a substantially greater proportion. It will be appreciated that the biocide composition may be provided as a concentrated solution which is subsequently diluted for use as an antimicrobial material. The higher concentrations of the biocide composition are useful, for example, in the bulk transportation of the composition. Thus, the amount of the composition of components (a) and (b) or (c) which is present in the biocide composition is typically in the range from 0.0001% up to 30% by weight of the biocide composition.

The composition of the present invention is especially effective in providing anti-bacterial activity. Thus, the compositions can be used for the treatment of various media to inhibit the growth of micro-organisms.

45 As a further aspect of the present invention there is provided a method for inhibiting the growth of micro-organisms on, or in, a medium which comprises treating the medium with a composition of components (a) and (b) or (c) as hereinbefore defined.

The composition can be used in conditions in which micro-organisms grow and cause problems. Systems in which micro-organisms cause problems include liquid, particularly aqueous, systems such as cooling water liquors, paper mill liquors, metal working fluids, geological drilling lubricants, polymer emulsions and surface coating compositions such as paints, varnishes and lacquers and also solid materials such as wood and leather. The composition of the present invention can be included in such materials to provide an anti-microbial effect. The amount of the composition is typically in the range from 0.0001 up to 10%, preferably 0.001 up to 5% and especially 0.002 to 1% by weight of the composition relative to the system to which it is added. In many cases, microbial inhibition has been obtained with between 0.005% and 0.1% by weight of the composition.

55 Components (a) and (b) or (c) of the composition of the present invention may be the only antimicrobial compounds or may be used together with further compounds having antimicrobial characteristics. The composition may contain more than one compound which is component (a) together with one or more compounds

which is either component (b) or component (c). Alternatively, a composition of components (a) and (b) or (c) in accordance with the present invention may be used together with one or more known antimicrobial compounds. The use of a mixture of anti-microbial compounds can provide a composition having a broader antimicrobial spectrum and hence one which is more generally effective than the components thereof. The known antimicrobial may be one possessing anti-bacterial, anti-fungal, anti-algal or other antimicrobial characteristic. The mixture of the composition of the present invention with other antimicrobial compounds typically contains from 1 to 99% by weight, relative to the weight of total antimicrobially active compounds, of the composition of components (a) and (b) or (c), and particularly from 40 to 60% by weight of the composition of components (a) and (b) or (c).

As examples of known antimicrobial compounds which may be used, together with the composition of the present invention, there may be mentioned quaternary ammonium compounds such as diethyldodecylbenzyl ammonium chloride; dimethyloctadecyl(dimethylbenzyl)ammonium chloride; dimethyldidecylammonium chloride; dimethyldidodecylammonium chloride; trimethyltetradecylammonium chloride; benzyldimethyl(C<sub>12</sub>-C<sub>18</sub> alkyl)ammonium chloride; dichlorobenzyltrimethylammonium chloride; hexadecylpyridinium chloride; hexadecylpyridinium bromide; hexadecyltrimethylammonium bromide; dodecylpyridinium chloride; dodecylpyridinium bisulphate; benzyldodecyl-bis(beta-hydroxyethyl)ammonium chloride; dodecylbenzyltrimethylammonium chloride; benzyldimethyl(C<sub>12</sub>-C<sub>18</sub> alkyl) ammonium chloride; dodecyldimethylethyl ammonium ethylsulphate; dodecyldimethyl-(1-naphthylmethyl)ammonium chloride; hexadecyldimethylbenzyl ammonium chloride; dodecyldimethylbenzyl ammonium chloride and 1-(3-chloroallyl)-3,5,7-triaza-1-azonia-adamantane chloride; urea derivatives such as 1,3-bis(hydroxymethyl)-5,5-dimethylhydantoin; bis(hydroxymethyl)urea; tetrakis(hydroxymethyl)acetylene diurea; 1-(hydroxymethyl)-5,5-dimethylhydantoin and imidazolidinyl urea; amino compounds such as 1,3-bis(2-ethylhexyl)-5-methyl-5-aminohexahydropyrimidine; hexamethylene tetra amine; 1,3-bis(4-aminophenoxy)propane; and 2-[(hydroxymethyl)-amino]ethanol; imidazole derivatives such as 1[2-(2,4-dichlorophenyl)-2-(2-propenyloxy)ethyl]-1H-imidazole; 2-(methoxycarbonylamino)-benzimidazole; nitrile compounds such as 2,4,5,6-tetrachloroisophthalodinitrile; thiocyanate derivatives such as methylene bis thiocyanate; tin compounds or complexes such as tributyltin-oxide, chloride, naphthoate, benzoate or 2-hydroxybenzoate; thiazole derivatives such as 2-(thiocyanomethylthio)-benzthiazole; and mercaptobenzthiazole; nitro compounds such as tris(hydroxymethyl)nitromethane; 5-bromo-5-nitro-1,3-dioxane and 2-bromo-2-nitropropane-1,3-diol; aldehydes and derivatives such as gluteraldehyde (pentanedial) p-chlorophenyl-3-iodopropargyl formaldehyde and glyoxal; amides such as chloracetamide; N,N-bis(hydroxymethyl)chloracetamide; N-hydroxymethyl-chloracetamide and dithio-2,2-bis(benzmethyl amide); guanidine derivatives such as poly hexamethylene biguanide and 1,6-hexamethylene-bis[5-(4-chlorophenyl)bi-guanide]; thiones such as 3,5-dimethyltetrahydro-1,3,5-2H-thiadiazine-2-thione; triazine derivatives such as hexahydrotriazine and 1,3,5-tri-(hydroxyethyl)-1,3,5-hexahydrotriazine; oxazolidine and derivatives thereof such as bis-oxazolidine; furan and derivatives thereof such as 2,5-dihydro-2,5-dialkoxy-2,5-dialkylfuran; carboxylic acids and the salts and esters thereof such as sorbic acid and the salts thereof and 4-hydroxybenzoic acid and the salts and esters thereof; phenol and derivatives thereof such as 5-chloro-2-(2,4-dichlorophenoxy)phenol; thio-bis(4-chlorophenol) and 2-phenylphenol; sulphone derivatives such as diiodomethyl-paratolyl sulphone, 2,3,5,6-tetrachloro-4-(methylsulphonyl) pyridine and hexachlorodimethyl sulphone.

Further aspects of the present invention are described in the following illustrative examples.

In the following examples, compositions in accordance with the present invention were subjected to evaluation of the antimicrobial properties of the compositions. The evaluation was effected, under sterile conditions throughout, as follows:

In the microbiological evaluation, various compositions were tested for anti-microbial activity against bacteria and fungi. The bacterium used was *Escherichia coli* and the fungus used was *Aspergillus niger*.

#### Microbiological evaluation

The materials, or mixture of materials, to be tested were added to a nutrient broth in amounts to give a desired concentration of the added material. The added materials were added at concentrations from zero to above the minimum inhibitory concentration of the particular material. In the mixtures, the concentrations of each material were varied in a systematic fashion to give a matrix of mixtures of different relative proportions and different total concentrations.

The effect on the inhibition of growth of bacteria was investigated by inoculating each sample of broth with sufficient of the test bacterium to give about  $10^5$  cells  $\text{cm}^{-3}$ . The mixture was incubated at 30°C for 48 hours. At the end of the test period the presence of turbidity in the broth indicated that growth of the test bacterium had occurred. A lack of turbidity was indicative that no growth had occurred. The results were used to draw an isobologram from which the sum of the fractional inhibitory concentration for a mixture can be determined.



**Example 1**

The microbiological evaluation as described was carried out using the bacterium, *Escherichia coli*. The composition tested was a mixture of 2-methyl-4,5-trimethylene-4-isothiazolin-3-one and 2-bromo-2-bromomethyl glutaronitrile.

An isobologram was drawn utilising concentrations of 0, 110, 221, 332, 444, 555, 665, 777, 888 and 1000 microgram  $\text{cm}^{-3}$  of the glutaronitrile and 0, 0.2, 0.5, 0.7, 0.9, 1.1, 1.4, 1.6, 1.8 and 2 microgram  $\text{cm}^{-3}$  of the isothiazolinone.

From the results obtained, it was found that the lowest sum of the fractional inhibitory concentration (FIC) was 0.61 which was achieved with a mixture containing 110 microgram  $\text{cm}^{-3}$  of the 2-bromo-2-bromomethyl glutaronitrile and 0.2 microgram  $\text{cm}^{-3}$  of the 2-methyl-4,5-trimethylene-4-isothiazolin-3-one. This may be contrasted with the minimum inhibitory concentrations (MIC) of the two individual components against the same micro-organism, which were found to be 221 microgram  $\text{cm}^{-3}$  and 1.8 microgram  $\text{cm}^{-3}$ , respectively.

**Example 2**

Example 1 was repeated, except the bacterium used was replaced by the fungus, *Aspergillus niger*.

Again, an isobologram was drawn utilising concentrations of 0, 166, 333, 500, 666, 833, 1000, 1166, 1333 and 1500 microgram  $\text{cm}^{-3}$  of the glutaronitrile and 0, 55, 111, 166, 221, 277, 332, 388, 444 and 500 microgram  $\text{cm}^{-3}$  of the isothiazolinone.

From the results obtained, it was found that the lowest sum of the FIC was 0.67 which was achieved with a mixture containing 500 microgram  $\text{cm}^{-3}$  of the 2-bromo-2-bromomethyl glutaronitrile and 111 microgram  $\text{cm}^{-3}$  of the 2-methyl-4,5-trimethylene-4-isothiazolin-3-one. Again, this may be contrasted with the two MIC values against the same micro-organism which were found to be 1500 and 332 microgram  $\text{cm}^{-3}$ , respectively.

The effect on the inhibition of growth of bacteria was investigated by inoculating each sample of broth with sufficient of the test micro-organism to give about  $10^5$  cells  $\text{cm}^{-3}$ . The mixture was incubated at  $30^\circ\text{C}$  for 48 hours. At the end of the test period the presence of turbidity in the broth indicated that growth of the test micro-organism had occurred. A lack of turbidity was indicative that no growth had occurred. The results were used to draw an isobologram from which the sum of the fractional inhibitory concentration for a mixture can be determined.

**Example 3**

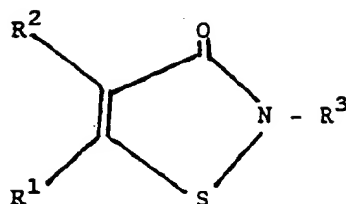
The microbiological evaluation as described was carried out using the bacterium, *Escherichia coli*. The composition tested was a mixture of 2-methyl-4,5-trimethylene-4-isothiazolin-3-one and 5-chloro-2-methyl-isothiazolin-3-one.

An isobologram was drawn using concentrations of 0, 0.2, 0.5, 0.7, 0.9, 1.1, 1.4, 1.6, 1.8 and 2 microgram  $\text{cm}^{-3}$  of the trimethylene-isothiazolinone and 0, 0.2, 0.5, 0.7, 0.9, 1.1, 1.4, 1.6, 1.8 and 2 microgram  $\text{cm}^{-3}$  of the chloro isothiazolinone.

From the results obtained, it was found that the lowest sum of the fractional inhibitory concentration was 0.54 which was obtained with a mixture of 0.2 microgram  $\text{cm}^{-3}$  of the 2-methyl-4,5-trimethylene-4-isothiazolin-3-one and 0.2 microgram  $\text{cm}^{-3}$  of the 5-chloro-2-methyl-isothiazolin-3-one. This may be contrasted with the minimum inhibitory concentrations (MIC) for the two individual compounds against the same micro-organism which were found to be 1.4 microgram  $\text{cm}^{-3}$  and 0.5 microgram  $\text{cm}^{-3}$  respectively.

**Claims**

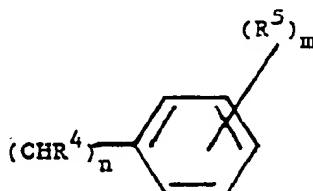
1. A composition which comprises
  - a) at least one 4,5-polymethylene-4-isothiazolin-3-one or a derivative thereof, and
  - b) at least one 2-halo-2-halomethyl glutaronitrile, or
  - c) at least one isothiazolin-3-one derivative which does not contain a fused ring attached to the isothiazole ring.
2. A composition as claimed in claim 1 wherein a) is at least one compound of the general formula:



wherein

R¹ and R² together represent a polymethylene chain having 3 or 4 carbon atoms, or a polymethylene chain having 3 or 4 carbon atoms substituted by at least one lower alkyl radical having from 1 to 4 carbon atoms;

R³ represents hydrogen, linear or branched alkyl having up to 12 carbon atoms, linear or branched alkyl having up to 3 carbon atoms substituted by at least one hydroxyl group, an alkenyl group having from 3 to 6 carbon atoms, a radical of the formula



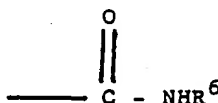
wherein

n is 0 or 1;

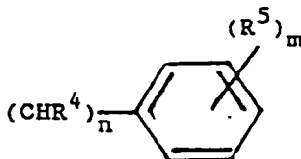
m is 1 or 2;

R⁴ represents hydrogen or alkyl having from 1 to 4 carbon atoms; and

R⁵ represents hydrogen, alkyl having from 1 to 4 carbon atoms, nitro, trifluoromethyl or halogen, cycloalkyl having from 3 to 6 carbon atoms, a radical of formula



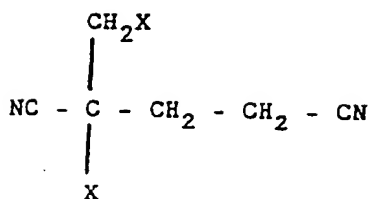
wherein R⁶ represents hydrogen, linear or branched alkyl having up to 12 carbon atoms or a radical of formula



as defined above, or their salts or complex with a mineral or organic acid, or with a base.

3. A composition as claimed in either claim 1 or claim 2 wherein component a) is either 4,5-trimethylene-4-isothiazolin-3-one or 2-methyl-4,5-trimethylene-4-isothiazolin-3-one.

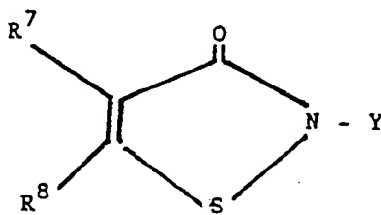
4. A composition as claimed in any one of claims 1 to 3 where component b) is at least one compound of general formula



wherein

each X, which may be the same or different, is a halogen atom.

5. A composition as claimed in any one of claims 1 to 4 wherein component b) is either 2-chloro-2-chloromethyl glutaronitrile or 2-bromo-2-bromomethyl glutaronitrile.
6. A composition as claimed in any one of claims 1 to 5 which comprises 2-methyl-4,5-trimethylene-4-isothiazolin-3-one and 2-bromo-2-bromomethyl glutaronitrile.
7. A composition as claimed in any one of claims 1 to 3 where component (c) is at least one compound of



wherein

Y is a hydrogen atom, an alkyl, substituted alkyl, alkenyl, alkynyl, cycloalkyl, aralkyl or aryl; and  
 R<sup>7</sup> is hydrogen, halogen or an alkyl group; and  
 R<sup>8</sup> is hydrogen, halogen or an alkyl group.

8. A composition as claimed in claim 7 wherein component (c) is selected from 2-methylisothiazolin-3-one, 5-chloro-2-methylisothiazolin-3-one and 4,5-dichloro-2-methylisothiazolin-3-one either alone or in combination.
9. A composition as claimed in claim 8 which comprises 2-methyl-4,5-trimethylene-4-isothiazolin-3-one together with at least one of 2-methylisothiazolin-3-one, 5-chloro-2-methylisothiazolin-3-one and 4,5-dichloro-2-methylisothiazolin-3-one.
10. A composition as claimed in any one of claims 1 to 9 which contains from one part by weight of component (a) or of component (b) or component (c) and up to 2000 parts by weight of component (b) or component (c) or component (a).
11. A composition as claimed in any one of claims 1 to 10 wherein the sum of the fractional inhibitory concentration of the components is less than 0.7.
12. A composition as claimed in any one of claims 1 to 11 which additionally includes a carrier.
13. A medium which is susceptible to attack by micro-organisms and which contains from 0.00001 to 10% by weight of the medium of a composition as claimed in any one of claims 1 to 12.
14. A medium as claimed in claim 13 which is selected from a cooling water system, a paper mill liquor, a metal working fluid, a geological drilling lubricant, a polymer emulsion, a paint, a lacquer, a varnish, a hydrocarbon fluid, an adhesive, a dyestuff or ink formulation, an agrochemical formulation, leather or wood.

15. A method for inhibiting the growth of micro-organisms on, or in, a medium, which comprises treating the medium with a composition as claimed in any one of claims 1 to 12.
- 5 16. A method for inhibiting the growth of micro-organisms on, or in, a medium, which comprises treating the medium with component (a) and component (b) sequentially, wherein
  - a) is at least one 4,5-polymethylene-4-isothiazolin-3-one or a derivative thereof, and
  - b) is at least one 2-halo-2-halomethyl glutaronitrile.
- 10 17. A method for inhibiting the growth of micro-organisms on, or in, a medium which comprises treating the medium with component (a) and component (c) sequentially, wherein
  - a) is at least one 4,5-polymethylene-4-isothiazolin-3-one or a derivative thereof, and
  - c) is at least one isothiazolin-3-one which does not contain a fused ring attached to the isothiazole ring.
- 15 18. A method as claimed in any one of claims 15 to 17 wherein the medium which is treated is a cooling water system, a paper mill liquor, a metal working fluid, a geological drilling lubricant, a polymer emulsion, a paint, a lacquer, a varnish, a hydrocarbon fluid, an adhesive, a dyestuff or ink formulation, an agrochemical formulation, leather or wood.

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